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(54) Ink jet recording device

(57) The device comprises a recording head (1) with a substantially linear array of nozzles (19) for the emission of droplets (45) of ink. Deflection means (25,27) for electrically charging and electrostatically deflecting the emitted droplets (45) are arranged in front of each nozzle (19) and the device further comprises transportation means (7,9) for transporting a record carrier (11) in such a manner that a surface of the record carrier faces the nozzles and moves in a direction (13) transverse to the array of the nozzles. The recording device is a droplet on demand recording device, each nozzle (19) communicating with a pressure chamber (17) associated with actuator means (15) for emitting an ink droplet (45) only when a predetermined signal is applied to the actuator means. The deflection means (25,27) are conceived to deflect the droplets over a range of angles in a direction substantially parallel to the array of the nozzles (19) and deflection control means (39) are provided to control the angle of deflection of the droplets so that the entire width of the record carrier (11) can be covered with ink droplets (45) from a single array of nozzles.

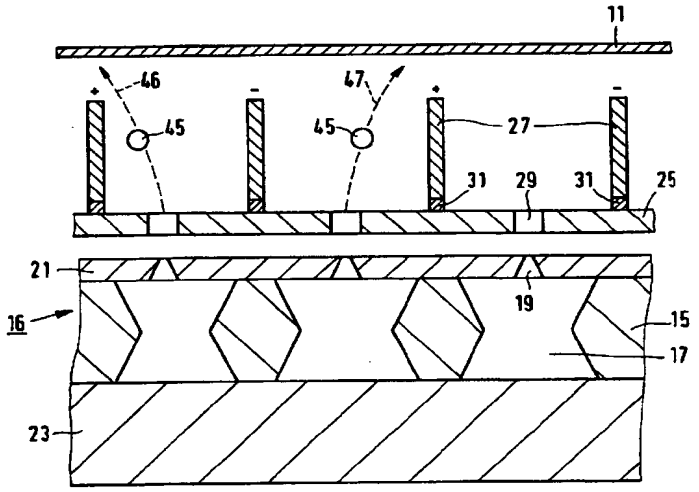

FIG.2

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Description

The invention relates to an ink jet recording device including a recording head comprising a substantially linear array of nozzles for the emission of droplets of ink, deflection means for electrically charging and electrostatically deflecting the emitted droplets being arranged in front of each nozzle, the device further comprising transportation means for transporting a record carrier in such a manner that a surface of the record carrier faces the nozzles and moves in a direction transverse to the array of the nozzles,

A device of this kind is known from US Re 28 219. The known device is a continuous ink jet system in which from each nozzle a continuous stream of ink droplets is emitted. The deflection means are conceived as a binary deflection system. The ink droplets either pass the deflection means without being deflected or they are deflected over a predetermined angle. Undeflected droplets travel on to the surface of the record carrier and deflected droplets are intercepted and transported back to an ink reservoir. The deflection means thus serve as a selection device for selecting the droplets that will be deposited on the record carrier.

The known device comprises a plurality of rows of parallel, equidistant nozzles. For constructional reasons, the distance between adjacent nozzles in the row is comparatively large. Consequently, gaps are formed between dots that are formed on the record carrier by droplets of ink emitted by adjacent nozzles. To enable the device to print a continuous line that extends over the whole width of the record carrier, the rows are laterally staggered. If droplets are emitted from a first row of nozzles with a suitable delay relative to the emission of droplets from a second row which is arranged upstream of the first row in the direction of transport of the record carrier, the droplets from the first and second rows will be deposited on a common line on the record carrier. If a sufficient number of rows is provided and if the delays between the emission of droplets from the different rows is controlled very precisely, it is possible to deposit a continuous line of droplets on the record carrier. It is clear that the device will be large due to the high number of rows of nozzles. Moreover, an expensive control mechanism having a high precision is required.

It is an object of the invention to provide an ink jet recording device that can print continuous monochrome lines on the record carrier with only a single row of nozzles. To achieve this object, the device in accordance with the invention is characterized in that the recording device is a droplet on demand recording device, each nozzle communicating with a pressure chamber associated with actuator means for emitting an ink droplet only when a predetermined signal is applied to the actuator means, the deflection means being conceived to deflect the droplets over a range of angles in a direction substantially parallel to the array of the nozzles, deflection control means being provided to control the angle of deflection of the droplets. Droplet on demand recording devices are well known in the art, sec e.g. US-A-4 599 628 and EP-A-0 516 188. Usually these devices comprise a relatively small printing head that can be displaced over the width of a record carrier as disclosed e.g. in US-A-4 491 854. The drive that is required for this displacement substantially increases the weight of the device and, moreover, the displacement takes time so that the speed of the device is relatively slow. The invention is based on the recognition of the fact that the electrostatic deflection of the ink droplets can be used to deposit droplets from a single nozzle in a plurality of positions on the record carrier so that each nozzle can print on a relatively large portion (e.g. in the order of magnitude of 1 mm) of the width of the record carrier. This makes it possible to print a line that continuously extends over the entire width of the record carrier with only a single array of nozzles and with a stationary recording head. If each nozzle covers approximately 1 mm of the width of the record carrier, an array comprising 210 nozzles would be sufficient to cover the width of a sheet of paper (A4).

A first embodiment of the device in accordance with the invention is characterized in that the deflection means comprise a plate-shaped charge electrode extending parallel to the array of nozzles and comprising apertures, an aperture being arranged in front of each nozzle, deflection electrodes being provided in front of the charge electrode in the vicinity of each aperture, the deflection control means comprising a charge voltage generator for supplying a charge voltage to the charge electrode and a deflection voltage generator for supplying a deflection voltage to the deflection electrodes. After leaving the nozzle an ink droplet first passes the aperture in the charge electrode where it receives an electrostatic charge that depends on the voltage supplied by the charge voltage generator. The charged droplet then passes between the deflection electrodes that cause it to be deflected over a predetermined angle. The angle of deflection depends, inter alia, on the charge of the droplet, the voltage between the deflection electrodes and the velocity of the droplet. For a given velocity the angle can be controlled by varying the charge voltage and/or the deflection voltage. A particularly simple variant of this embodiment is characterized in that one of the said charge and deflection voltage generators is conceived to supply a voltage that varies as a function of time, the other voltage generator being conceived to supply a voltage that is substantially constant. In this variant only one of the voltage generators has to be of a controllable type.

A second embodiment of the device in accordance with the invention is characterized in that the deflection means comprise a plurality of pairs of deflection electrodes, one pair being arranged in front of each nozzle, the deflection electrodes of a pair being arranged at opposite sides of the nozzle as viewed in the direction of the array of nozzles, each deflection electrode comprising an electrically conductive plate having a first portion and a second portion, the first portion of each deflection

electrode extending away from the nozzles, the second portion of each deflection electrode being located near the array of nozzles, the deflection control means comprising voltage generator means that are conceived to supply first voltage pulses to a first one of the deflection electrodes of each pair and to supply second voltage pulses to the second one of the deflection electrodes of each pair, the first and second voltage pulses having the same polarity and the same amplitude and starting at the same time, the duration of the first voltage pulse being different from the duration of the second voltage pulse. This embodiment is particularly simple from a constructional point of view because it does not comprise a separate charge electrode. The combination of the first and second voltage pulses serves to charge and to deflect the ink droplet. Preferably, the first portions of the deflection electrodes of a pair are arranged at a larger distance from each other than the second portions. Due to the close proximity of the second portions of the deflection electrodes to each other and to the nozzle the process of charging the emitted droplets is very efficient. The greater distance between the first portions allows for the space necessary for the movement of the droplet in a direction parallel to the array of nozzles, which movement is caused by the deflection. Various constructions for achieving this difference in distance are possible. A first construction is characterized in that the second portion of each deflection electrode extends substantially at right angles to the first portion, the first portion extending substantially perpendicularly to the array of nozzles, and the second portion extending substantially parallel to the array of nozzles, the second portion of each deflection electrode of a pair extending toward the other deflection electrode of the pair. A second construction is characterized in that the deflection electrodes have a curved shape, the second portions extending substantially at right angles to the array of nozzles.

The recording device in accordance with the invention can be modified for multicolour printing. An embodiment of a device adapted for this purpose is characterized in that the recording head comprises a plurality of substantially parallel linear arrays of nozzles, the nozzles in different arrays being adapted to emit ink droplets of different colours. If the nozzles of each array communicate with pressure chambers that are supplied with ink of one of four basic colours (usually magenta, cyan, yellow and black), four arrays are sufficient to obtain a full colour print on the record carrier. It is, of course, necessary to introduce suitable delays between the emission of droplets from the different arrays in order to ensure that differently coloured droplets that contribute to the same portion of an image to be formed are deposited on the same line on the record carrier.

A variant of the recording device for multicolour printing is characterized in that the recording head comprises first and second substantially linear arrays of nozzles, adjacent nozzles in the first array being adapted to emit ink droplets having first and second colours, respectively, adjacent nozzles in the second array being adapted to emit ink droplets having third and fourth colours, respectively, the first, second, third and fourth colours being mutually different. It has been found that the deflection of the ink droplets makes it possible to deposit two colours with a single array of nozzles. Droplets of different colours emitted by adjacent nozzles can be deflected so that they overlap on the record carrier. Thereby four basic colours can be deposited by means of only two arrays of nozzles. A multicolour recording device having these features can be very simple and light in weight.

These and other aspects of the invention will be apparent from the embodiments described hereinafter.

Figure 1 is a schematic view of an embodiment of an ink jet recording device in accordance with the invention,

Figure 2 is a partial cross-section of a first embodiment of a recording head of the device shown in Fig. 1,

Figure 3 is a view from above of the recording head shown in Fig. 2,

Figure 4 is a block diagram of a control unit of the device shown in Fig. 1,

Figure 5 is a diagram showing an example of a voltage to be applied to electrodes of the recording head shown in Fig. 2,

Figures 6A and 6B are partial cross-sections of two variants of a second embodiment of a recording head of the device shown in Fig. 1,

Figure 7 is a view from above of the recording head shown in Fig. 6B,

Figure 8 is a diagram showing examples of voltages to be applied to electrodes of the recording heads shown in Figures 6A and 6B,

Figure 9 is a view from above of a third embodiment of a recording head of the device shown in Fig. 1, and

Figure 10 is a view from above of a modified embodiment of a recording head of the device shown in Fig. 1.

Figure 1 is a schematic representation of an ink jet recording device showing at least those parts that are necessary to provide sufficient background for understanding the invention. The device comprises a recording head 1 comprising a substantially linear array of nozzles for the emission of droplets of ink. This array of nozzles is not visible in Fig. 1. It extends parallel to the dash-dot line 3. The nozzles face a waiting and servicing station 5 for keeping the recording head in a proper condition when the device is not in use. An ink container 6 is provided for supplying ink to the recording head 1. The device further comprises transportation means in the form of a pair of cooperating rollers 7 that are driven by means of a motor 9. The rollers 7 serve to transport a record carrier 11, usually a sheet of paper, in such a manner that it moves between the recording head 1 and

the waiting and service station 5 in a direction transverse to the array of nozzles as indicated by the arrow 13. When it is transported in this manner, a surface of the record carrier (the surface that is directed downward in Fig. 1) faces the nozzles. A control unit 14 is provided to control the operation of the device.

Figure 2 shows a cross-section of a first embodiment of the recording head 1 taken along a line parallel to the line 3 in Fig. 1. This recording head comprises a plurality of piezoelectric actuator elements 15 provided in an actuator plate 16 that comprises a plurality of layers of a ceramic piezoelectric material alternated with electrode layers (not shown). The actuator plate 16 is provided with recesses 17 that constitute pressure chambers, an actuator element 15 cooperating with each pressure chamber. The pressure chambers 17 are connected to the ink container 6 (Fig. 1) by means of an ink supply system, not shown. A detailed description of a recording head of this type can be found in the copending patent application No. ... (PHN 15.079), incorporated herein by reference. Each pressure chamber 17 communicates with a nozzle 19 provided in a nozzle plate 21 that covers one side of the pressure chambers. As indicated above, the nozzles 19 are arranged in a substantially linear array that extends parallel to the line 13. The opposite side of the pressure chambers 17 is covered by a backing plate 23. When a suitable voltage is applied to one of the actuator elements 15, the associated pressure chamber 17 contracts and a droplet of ink is emitted from the associated nozzle 19. A system of this kind is known as a droplet on demand system as opposed to a continuous jet system in which a continuous stream of droplets is generated as disclosed in US Reissue No. 28 219.

Deflection means are arranged in front of each nozzle 19 so that the droplets of ink emitted by the nozzles have to pass these deflection means. In the embodiment shown in Fig. 2 the deflection means comprise a plate-shaped charge electrode 25 and deflection electrodes 27 arranged in front of the charge electrode. The charge electrode 25 extends parallel to the array of nozzles 19 and comprises apertures 29, one of these apertures being arranged in front of each nozzle. The deflection electrodes 27 are also plate-shaped. They extend substantially at right angles to the charge electrode 25. In this embodiment a deflection electrode 27 is provided halfway between each pair of adjacent apertures 29. The charge electrode 25 and the deflection electrodes 27 are electrically conductive. Each deflection electrode 27 is electrically isolated from the charge electrode by means of an insulating bottom part 31. The charge electrode 25 and the deflection electrodes 27 may be formed from metal plates, e.g. nickel plates. In that case the deflection electrodes 27 may be mechanically connected to the charge electrode 25 by means of an electrically insulating adhesive that forms the bottom part 31. Alternatively, the charge electrode 25 and the deflection electrodes 27 may be formed as a single structure from an electrically insulating material such as glass, the structure with the exception of the bottom parts 31 then being covered with an electrically conductive film, e.g. by evaporation in a vacuum of a suitable metal.

Figure 3 shows a view from above of the recording head shown in Fig. 2. One of the pressure chambers 17 is indicated in dotted lines. It can be seen that the charge electrode 25 covers the nozzle plate 21 in the vicinity of the nozzles 19 that are visible through the apertures 29, the deflection electrodes 27 being arranged near the apertures.

Figure 4 shows a block diagram of the control unit 14 of the recording device shown in Fig. 1. The control unit 14 comprises a central control unit 33 which may comprise a microprocessor and which controls motor control means 35 for controlling the motor 9, emission control means 37 for controlling the emission of ink droplets, and deflection control means 39 for controlling the deflection of the emitted ink droplets. In the embodiment shown in Figures 2 and 3 the deflection control means 39 comprise a charge voltage generator 41 for supplying a charge voltage to the charge electrode 25 and a deflection voltage generator 43 for supplying a deflection voltage to the deflection electrodes 27. The central control unit 33 coordinates the functioning of the control means 35, 37 and 39 so that droplets of ink are deposited on desired locations on the surface of the record carrier 11.

The operation is as follows: When a droplet of ink is ejected from a nozzle 19, it passes through the associated aperture 29 in the charge electrode 25. The output terminals of the charge voltage generator 41 are electrically connected between the ink supply system (e.g. the ink container 6 or the nozzle plate 21) and the charge electrode 25. Consequently, the charge electrode 25 is kept at a predetermined voltage relative to the ink in the pressure chambers 17. As a result, an ink droplet that passes through the aperture 29 acquires an electrostatic charge that depends on the charge voltage supplied by the charge voltage generator 41. The terminals of the deflection voltage generator 43 are connected to the deflection electrodes 27 in such a manner that each time the two deflection electrodes at either side of an aperture 29 are connected to different terminals of the deflection voltage generator. Consequently, successive deflection electrodes 27 have opposite polarities as indicated be the signs + and - in Fig. 2. As a result an electrostatic deflection field is established between each pair of deflection electrodes 27, the deflection field being directed parallel to the array of nozzles 19. This deflection field causes a charged droplet of ink 45 to follow a curved trajectory, two examples being shown by dotted lines 46 and 47 in Fig. 2. As a result of the different polarities of successive deflection electrodes 27 the droplets ejected from adjacent nozzles 19 are deflected in opposite directions. Because the charge voltage and the magnitude of the deflection voltage is the same for all droplets, the deflection angle is also the same. The deflection angle of all droplets can be controlled by var-

ying the charge voltage and/or the deflection voltage. In order to make the control of the device as simple as possible, one of these voltages is preferably kept constant. The other voltage is then varied to control the deflection angle of the ink droplets in such a manner that for the maximum deflection the points of intersection of adjacent trajectories 46, 47 with the record carrier 11 coincide if the two trajectories are curved toward each other. It is then possible to cover the whole width of the record carrier 11 with droplets. For a given deflection angle a droplet 45 ejected from a nozzle 19 is deposited on the record carrier at a position that is displaced over a given distance parallel to the line 3 relative to the position directly opposite the nozzle. If it is desired to deposit an ink droplet at that position, the central control unit 33 causes the emission control unit to supply a signal to the relevant actuator element 15. If not, no droplet is emitted.

Figure 5 is a diagram showing an example of the charge voltage as a function of time. As noted before, this varying charge voltage is preferably combined with a constant deflection voltage. Alternatively, the deflection voltage may be varied as shown in Fig. 5, the charge voltage being kept constant. The charge voltage V starts at a maximum negative value $-V_{max}$ and is increased in steps to a maximum positive value $+V_{max}$, each step corresponding to a discrete deflection angle. In this example the number of steps is ten and the time it takes to perform all steps is T. The charge voltage is then reduced to $-V_{max}$ in a single step to begin the next cycle. The charge voltage is therefore similar to a sawtooth voltage. It is also possible to decrease the charge voltage in steps during a time T so that the charge voltage is similar to a triangular voltage. Instead of varying the charge voltage in steps, it may also be varied continuously, e.g. linearly. In that case the deflection angle too varies continuously. A variation of the charge voltage between $-V_{max}$ and $+V_{max}$ corresponds to a variation of the deflection angle of the ink droplets between its two extreme values, that is over the whole range of possible values. During the time interval T the central control unit 33 prevents the motor control means 35 from energizing the motor 9 so that the transport of the record carrier 11 is interrupted. Consequently, all droplets ejected by the nozzles 19 during this interval are deposited on the record carrier on a single line parallel to the line 3.

As stated above, the output terminals of the charge voltage generator 41 are preferably connected between the ink supply system and the charge electrode 25. For a stable operation it is preferred that the ink supply system and the record carrier 11 are grounded. The record carrier may be in contact with a grounded metal brush (not shown) serving as a drain electrode for electrostatic charges. At the side of the record carrier 11 that faces away from the recording head 1 a backing electrode in the form of an electrically conductive surface may be provided (for example a part of the waiting and service station 5) to which a predetermined voltage is applied. This has the advantage that an ink droplet may have a high initial velocity which is preferable for a good emission of the droplets. The voltage applied to the backing electrode then serves to slow down the droplets so that they do not travel too fast through the deflection field to be properly deflected.

In the first embodiment as discussed above, the deflection means associated with each pair of adjacent nozzles 19 share a common deflection electrode 27. As a result, the ink droplets emitted by adjacent nozzles 19 are deflected simultaneously in opposite directions. It is also possible to provide two deflection electrodes 27 between each pair of nozzles 19, the two deflection electrodes being electrically isolated from each other and being electrically connected to different terminals of the charge voltage generator 41. In that case the droplets emitted by adjacent nozzles 19 are deflected simultaneously in the same direction.

Figure 6 shows a cross-section of a portion of a recording head of a second embodiment of the invention, Fig. 6A showing a first variant and Fig. 6B showing a second variant. The construction of the droplet-emitting portion of the recording head is similar to the construction of the first embodiment shown in Fig. 2. For the sake of simplicity only the nozzle plate 21 of this construction is shown in Fig. 6.

In the second embodiment the combination of charge electrodes 25 and deflection electrodes 27 of the first embodiment has been replaced by an electrode arrangement comprising a plurality of pairs of deflection electrodes 48. One pair of deflection electrodes 48 is arranged in front of each nozzle 19 in such a manner that one electrode of the pair is located to the left of the nozzle opening and the other one is located to the right in Fig. 6. In other words, the two deflection electrodes 48 of the pair are located at opposite sides of the nozzle 19 as viewed in the direction of the array of nozzles. Each deflection electrode 48 comprises an electrically conductive plate having a first portion 49 that extends away from the nozzle 19 and a second portion 50 that is located near the array of nozzles. The plates may be, for example, metal plates or metallized insulating plates. The first portions 49 of the deflection electrodes 48 of a pair are arranged at a larger distance from each other than the second portions 50. The result is that the second portions 50 define a narrow slit 51 between them through which the ejected ink droplet has to pass. During the passage of the droplet through the slit 51 the deflection electrodes 48 are kept at a predetermined potential relative to the ink supply system or the nozzle plate 21. The droplet thus acquires an electrostatic charge of a magnitude depending on this voltage. When the droplet has passed the slit 51, a predetermined voltage is applied between the two electrodes 48 of a pair that is associated with a common nozzle 19. An electrostatic deflection field is generated thereby between the electrodes 48 which causes the charged droplet to be deflected as it continues its way between the first portions 49 of the deflection electrodes. This means that the deflection electrodes 48 have a double function:

they serve to apply an electrostatic charge to the ink droplets ejected by the nozzles 19 and to deflect the charged droplets over a controllable deflection angle.

In the variant shown in Fig. 6A the second portion 50 of each deflection electrode 48 extends substantially at right angles to the first portion 49. The first portion 49 extends perpendicularly to the array of nozzles 19 and the second portion 50 extends parallel to the array of nozzles. The deflection electrodes 48 in this variant are L-shaped in cross-section with the second portion 50 of each deflection electrode of a pair extending toward the other deflection electrode of the pair. In the variant shown in Fig. 6B the deflection electrodes 48 have a curved shape that substantially follows the path of an ink droplet having the maximum angle of deflection. The second portions 50 extend substantially at right angles to the array of nozzles 19.

Because it must be possible to apply a voltage between the two electrodes 48 of a pair, the electrodes to the left of the nozzles 19 are all connected to a first common terminal and the electrodes to the right of the nozzles are all connected to a second common terminal. This can be seen in Figure 7 which shows a top view of the variant shown in Fig. 6B. In Fig. 7 the first and second terminals are indicated with 53 and 55, respectively. Each terminal 53, 55 together with the electrodes connected to it forms a comb-like structure, the two structures being interleaved. The first and second terminals 53 and 55 are connected to terminals of a voltage generator that is part of the deflection control means 39 shown in Fig. 4.

Figure 8 is a diagram illustrating an example of the voltages that may be applied to the terminals 53, 55. In this example a first voltage V_1 is applied to the first terminal 53 and a second voltage V_2 is applied to the second terminal 55. The first voltage V_1 comprises a series of first voltage pulses, two pulses 57 and 59 being shown in Fig. 8. The duration of successive first voltage pulses is varied in a predetermined manner. In Fig. 8 it is shown that the first one of the first voltage pulses (57) starts at a time t_1 and ends at t_3 whereas the second one (59) starts at t_4 and ends at t_6, the interval $t_6 - t_4$ exceeding the interval $t_3 - t_1$. In a practical embodiment the duration of the first voltage pulses would progressively increase from a minimum value $t_2 - t_1$ ($=t_5 - t_4$) to a predetermined maximum value (not shown). The second voltage V_2 comprises a series of second voltage pulses such as 61 and 63 that have the same duration $t_2 - t_1$ ($=t_5 - t_4$). Therefore, the corresponding first and second voltage pulses start at the same time and generally have different durations (as noted above, the first voltage may comprise a voltage pulse that has the same duration as the pulses of the second voltage). The amplitudes A and the polarities of the first and second voltage pulses are the same.

At the time t_1 the first voltage pulse 57 is applied to the first terminal 53 which is connected to the deflection electrodes 48 that are situated to the left of the associated nozzles 19, the second voltage pulse 61 being applied to the second terminal 55 which is connected to the deflection electrodes situated to the right of the corresponding nozzles. Because the amplitudes A and the polarities of the two pulses 57 and 61 are the same, the deflection electrodes 48 at both sides of a nozzle 19 are at the same potential relative to the ink supply system of the nozzle plate 21 during the interval $t_2 - t_1$. An ink droplet that is ejected at the beginning of this interval passes the second portions 50 of the deflection electrodes 48 during this interval and receives an electrostatic charge. At the time t_2 the second pulse 61 ends and the first pulse 57 continues with the same amplitude. As a result, there is now an electrostatic field between the two deflection electrodes 48 at either side of the nozzle 19. Due to this field the charged droplet is deflected away from the electrode 48 that is connected to the first terminal 53. This deflection takes place during the passage of the droplet between the first portions 49 of the deflection electrodes 48. The angle of deflection depends on the amplitude A of the first and second pulses 57, 61, on the duration $t_2 - t_1$ of the second pulse 61 and on the time $t_3 - t_2$ by which the duration of the first pulse 57 exceeds that of the second pulse 61. Consequently, a first method for controlling the angle of deflection comprises varying the duration of the first pulse 57. This is done in the example shown in Fig. 8: the next pulse 59 is longer than the pulse 57. After the maximum duration of the first pulses has been reached, the first voltage V_1 must be applied to the second terminal 55 and the second voltage V_2 to the first terminal 53 in order to deflect the ink droplets in the opposite direction. A further strategy for controlling the angle of deflection is a variation of the duration of the second pulse 61 in order to control the electrostatic charge applied to the droplet. This method makes use of the fact that the angle of deflection increases with increasing charge if the deflection field is the same. A still further method for controlling the angle of deflection is a variation of the amplitude A of the first and second pulses.

Figure 9 is a view from above of a recording head for a multicolour ink jet recording device. The Figure is similar to Fig. 3 and the same reference numerals have been used as far as possible. The recording head comprises two substantially parallel linear arrays of nozzles, a first array 65 and a second array 67. The first array 65 comprises two types of nozzles, a first type 19a and a second type 19b. The nozzles of the first and second types are alternatingly arranged in the first array. Similarly, nozzles of a third type 19c and a fourth type 19d are alternatingly arranged in the second array 67. The difference between the four types of nozzles is that they communicate with pressure chambers that are connected to ink supply systems filled with inks of different colours. In this manner the nozzles of the different types are adapted to emit ink droplets of different colours. For example, the nozzles 19a, 19b, 19c and 19d respectively emit magenta, cyan, black and yellow ink. The pitch of the nozzles and the maximum angle of deflection of the ink droplets are chosen such that droplets

emitted by a nozzle can be deflected so far that they are deposited on points on the record carrier 11 that are situated opposite the two adjacent nozzles. Thus a droplet emitted by one of the nozzles 19a of the first type can be deposited in front of each one of the two adjacent nozzles 19b of the second type and in every intermediate position. Consequently, the recording head permits the deposition of ink droplets of the two colours emitted by the nozzles 19a and 19b of the first array 65 over the entire width of the record carrier 11. Similarly, ink droplets emitted by the nozzles 19c and 19d of the second array 67 can be deposited over the entire width of the record carrier 11. As shown in Fig. 1, the record carrier 11 is transported in a direction 13 at right angles to the direction of the arrays 65 and 67. Therefore, if the emission of ink droplets by the nozzles 19c and 19d of the second array 67 is delayed for an appropriate interval relative to the emission by the nozzles 19a and 19b of the first array 65, the ink droplets from all four types of nozzles are deposited on the same line extending over the width of the record carrier 11. The required delay can easily be computed from the velocity of the record carrier 11 and the distance between the two arrays 65 and 67. The central control unit 33 can be programmed to control the delay. It is clear that a very compact and inexpensive multicolour ink jet recording device can be obtained by using the recording head shown in Fig. 8. Modifications of the arrangement shown are possible. For example, three or four arrays could be used, each array being devoted to a single colour.

Figure 10 is a view from above of a slightly modified recording head similar to the recording head shown in Fig. 3. In this recording head the nozzles 19 are slightly staggered. They form a linear array that extends as a zigzag line having a general direction indicated by the line 69. This arrangement has the advantage that the pitch of the array of nozzles 19 can be smaller than when the nozzles are arranged strictly according to a straight line as in Fig. 3. Thus, the recording speed of the device can be increased or a redundancy can be built in because the droplets emitted by adjacent nozzles 19 can be deposited at the same positions on the record carrier 11. Of course, it is necessary to apply a suitable delay to the emission of the droplets from the different nozzles 19 in order to obtain a straight line on the record carrier 11. This zigzag arrangement of the nozzles can also be used in each one of the arrays 65 and 67 of the recording head shown in Fig. 9.

Claims

1. An ink jet recording device including a recording head (1) comprising a substantially linear array of nozzles (19) for the emission of droplets (45) of ink, deflection means (25,27) for electrically charging and electrostatically deflecting the emitted droplets being arranged in front of each nozzle, the device further comprising transportation means (7,9) for transporting a record carrier (11) in such a manner that a surface of the record carrier faces the nozzles and moves in a direction (13) transverse to the array of the nozzles, characterized in that the recording device is a droplet on demand recording device, each nozzle (19) communicating with a pressure chamber (17) associated with actuator means (15) for emitting an ink droplet (45) only when a predetermined signal is applied to the actuator means, the deflection means (25,27) being conceived to deflect the droplets over a range of angles in a direction substantially parallel to the array of the nozzles, deflection control means (39) being provided to control the angle of deflection of the droplets.

2. An ink jet recording device as claimed in Claim 1, characterized in that the deflection means comprise a plate-shaped charge electrode (25) extending parallel to the array of nozzles (19) and comprising apertures (29), an aperture being arranged in front of each nozzle, deflection electrodes (27) being provided in front of the charge electrode in the vicinity of each aperture, the deflection control means (39) comprising a charge voltage generator (41) for supplying a charge voltage to the charge electrode and a deflection voltage generator (43) for supplying a deflection voltage to the deflection electrodes.

3. An ink jet recording device as claimed in Claim 2, characterized in that one of the said charge and deflection voltage generators (41,43) is conceived to supply a voltage (V) that varies as a function of time, the other voltage generator being conceived to supply a voltage that is substantially constant.

4. An ink jet recording device as claimed in Claim 1, characterized in that the deflection means comprise a plurality of pairs of deflection electrodes (48), one pair being arranged in front of each nozzle (19), the deflection electrodes of a pair being arranged at opposite sides of the nozzle as viewed in the direction of the array of nozzles, each deflection electrode comprising an electrically conductive plate having a first portion and a second portion, the first portion (49) of each deflection electrode extending away from the nozzles, the second portion (50) of each deflection electrode being located near the array of nozzles, the deflection control means (39) comprising voltage generator means that are conceived to supply first voltage pulses (57) to a first one of the deflection electrodes of each pair and to supply second voltage pulses (61) to the second one of the deflection electrodes of each pair, the first and second voltage pulses having the same polarity and the same amplitude (A) and starting at the same time, the duration of the first voltage pulse being different from the duration of the second voltage pulse.

5. An ink jet recording device as claimed in Claim 4, characterized in that the first portions (49) of the deflection electrodes (48) of a pair are arranged at a larger distance from each other than the second portions (50).

6. An ink jet recording device as claimed in Claim 5, characterized in that the second portion (50) of each deflection electrode (48) extends substantially at right angles to the first portion (49), the first portion extending substantially perpendicularly to the array of nozzles (19), and the second portion extending substantially parallel to the array of nozzles, the second portion of each deflection electrode of a pair extending toward the other deflection electrode of the pair.

7. An ink jet recording device as claimed in Claim 5, characterized in that the deflection electrodes (48) have a curved shape, the second portions (50) extending substantially at right angles to the array of nozzles (19).

8. An ink jet recording device as claimed in any one of Claims 4 to 7, characterized in that the deflection control means (39) comprise means for varying the duration of the first voltage pulse (57).

9. An ink jet recording device as claimed in any one of Claims 4 to 8, characterized in that the deflection control means (39) comprise means for varying the duration of the second voltage pulse (61).

10. An ink jet recording device as claimed in any one of Claims 4 to 7, characterized in that the deflection control means (39) comprise means for varying the amplitude (A) of the first and second voltage pulses (57,61).

11. An ink jet recording device as claimed in any one of the preceding Claims, characterized in that the recording head comprises a plurality of substantially parallel linear arrays (65,69) of nozzles (19a,... 19d), the nozzles in different arrays being adapted to emit ink droplets of different colours.

12. An ink jet recording device as claimed in Claim 11, characterized in that the recording head comprises first and second substantially linear arrays of nozzles, adjacent nozzles (19a, 19b) in the first array (65) being adapted to emit ink droplets having first and second colours, respectively, adjacent nozzles (19c, 19d) in the second array (67) being adapted to emit ink droplets having third and fourth colours, respectively, the first, second, third and fourth colours being mutually different.

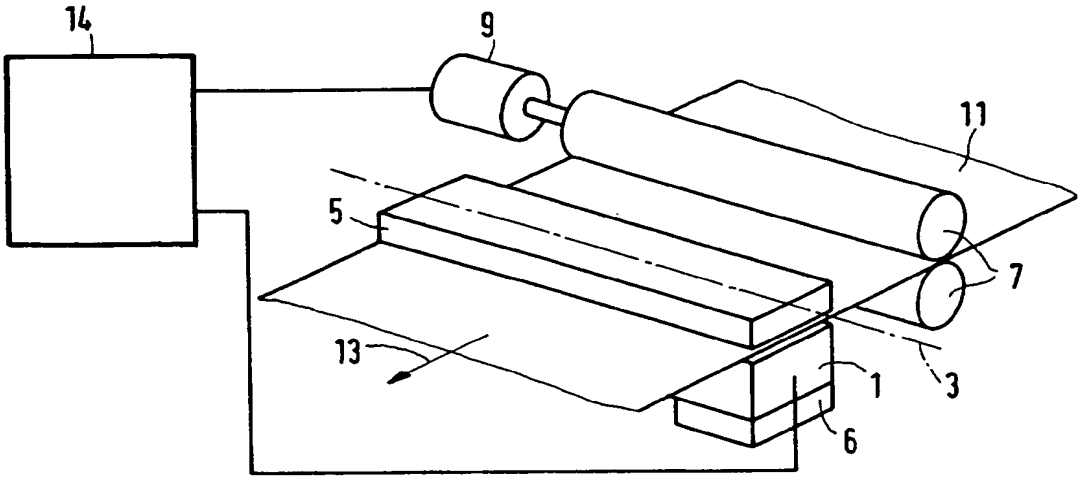

FIG.1

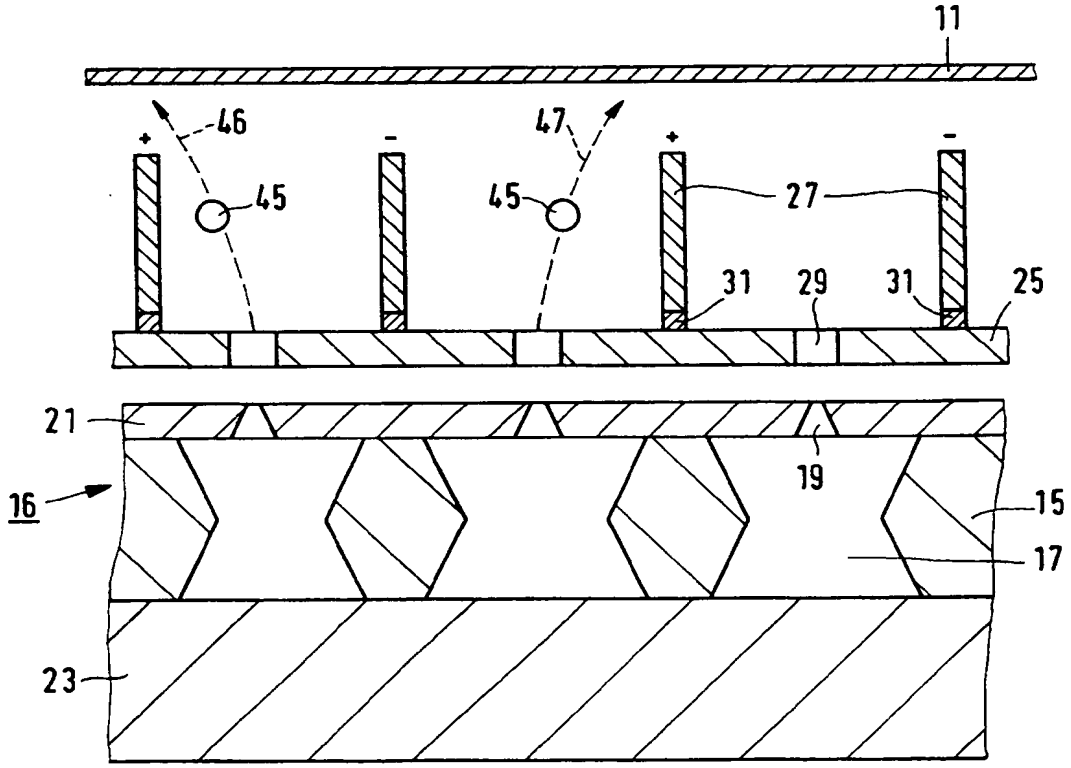

FIG.2

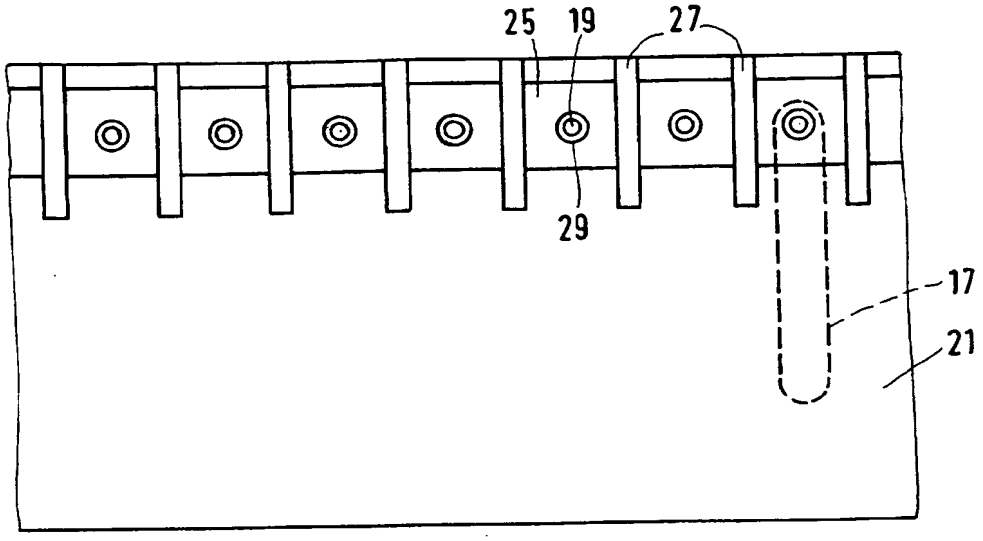

FIG.3

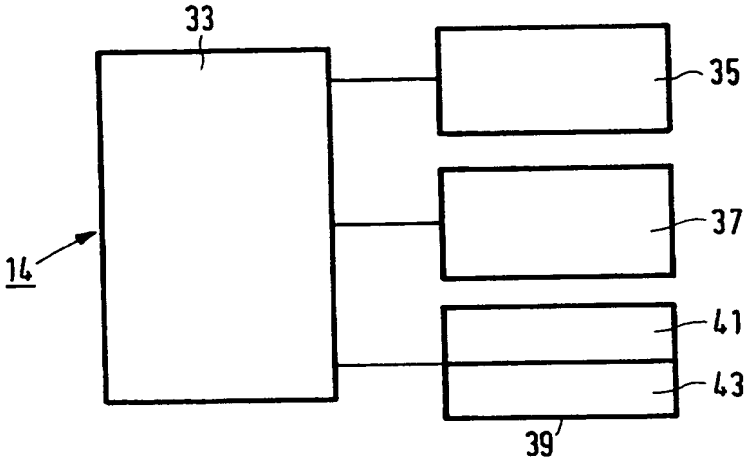

FIG.4

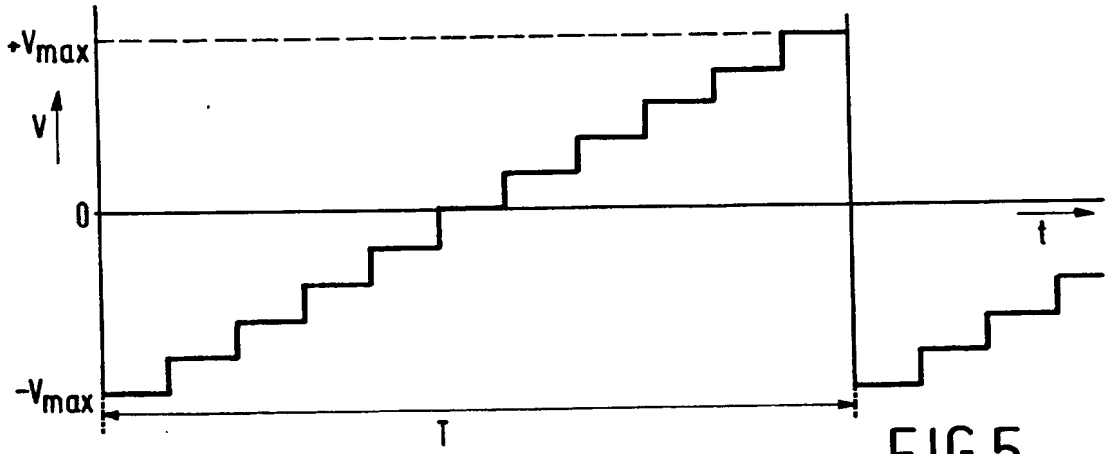

FIG.5

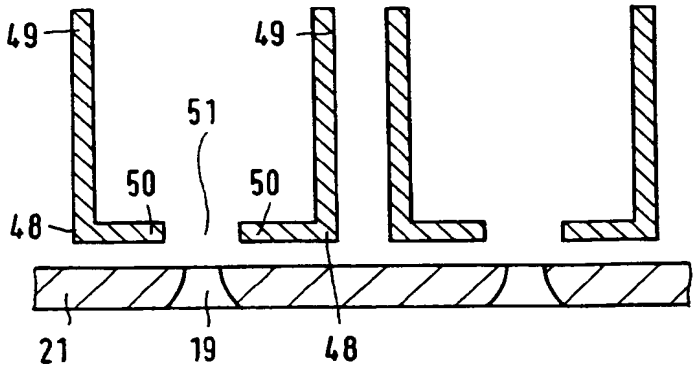

FIG.6A

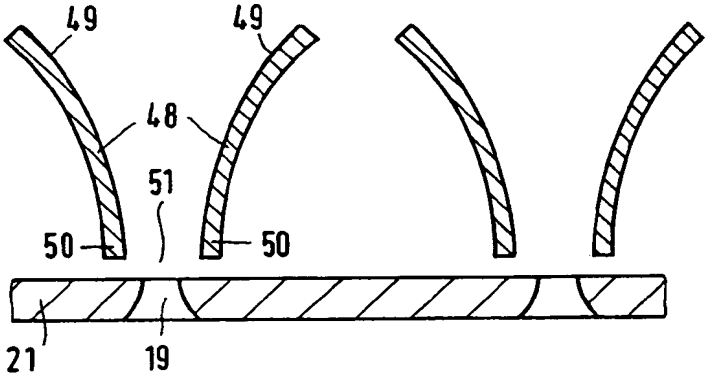

FIG.6B

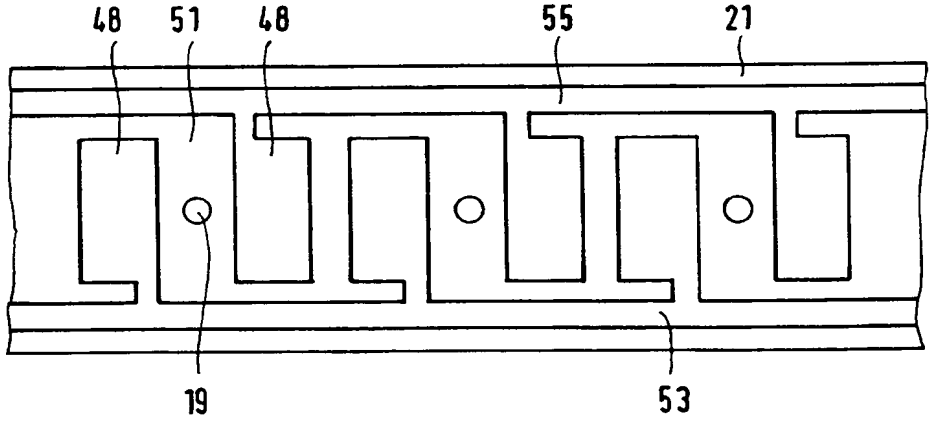

FIG.7

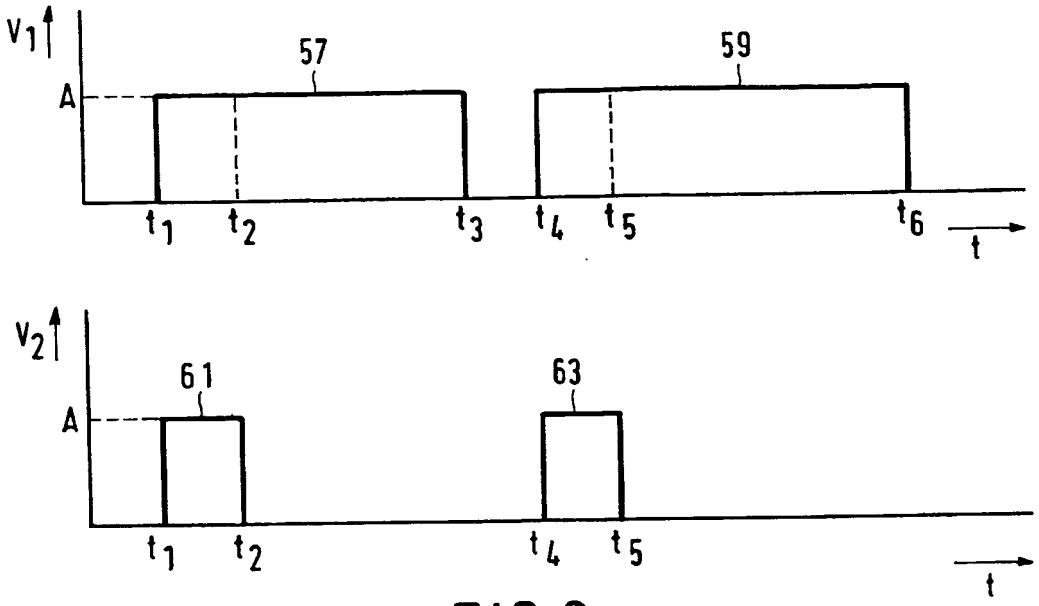

FIG.8

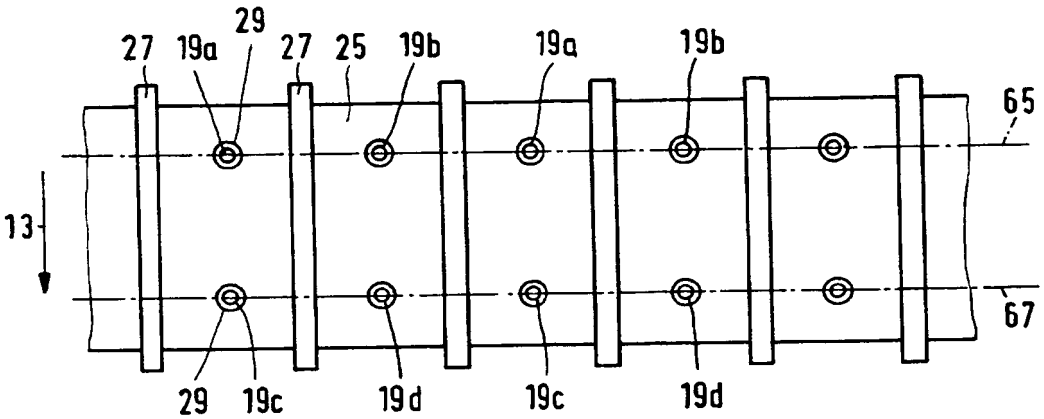

FIG.9

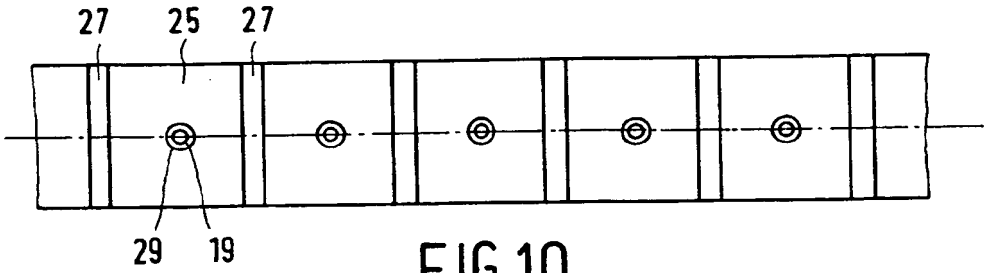

FIG.10

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 20 2047

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	PATENT ABSTRACTS OF JAPAN vol. 4 no. 92 (M-18) [574] ,3 July 1980 & JP-A-55 049277 (RICOH K.K.) 9 April 1980,	1,2,4	B41J2/075 B41J2/115
Y	* abstract *	3,5-10	

Y	DE-A-41 36 402 (SR TECHNOS LTD.)	3,8-10	
A	* column 3, line 68 - column 4, line 47 * * column 6, line 28 - column 9, line 40 * * column 12, line 25 - column 13, line 61; figures 1-4,7,8 *	1,4	

Y	GB-A-2 089 735 (PITNEY BOWES INC.)	5,7	
A	* page 2, line 35 - line 43 * * page 3, line 1 - page 4, line 31; figures 1-11 *	1-4,11, 12	

Y	PATENT ABSTRACTS OF JAPAN vol. 5 no. 43 (M-60) [715] ,23 March 1981 & JP-A-55 166261 (RICOH K.K.) 25 December 1980,	5,6	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	* abstract *	1	B41J

X	US-A-4 382 263 (FISCHBECK ET AL.)	1	
A	* column 2, line 63 - column 4, line 68; figures 3A-3B 4B *	2-10	

X	US-A-4 389 652 (FISCHBECK)	1,4	
A	* column 3, line 66 - column 4, line 53; figures 4,6 *	2,3,5-10	

A	PATENT ABSTRACTS OF JAPAN vol. 6 no. 41 (P-106) [919] ,13 March 1982 & JP-A-56 157588 (NIPPON DENKI K.K.) 4 December 1981, * abstract *	1-10	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 November 1995	Rivero, C

EPO FORM 1503 03.82 (P04C01)

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E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

Application Number
EP 95 20 2047

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	US-A-4 393 385 (JINNAI ET AL.) * column 3, line 20 - column 5, line 47; figures 3-7 * -----	1-4,8-10	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

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EPO FORM 1503 03.82 (P04C01)